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Low-Speed Wind Tunnel Tests on a Diamond Wing High Lift Configuration

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On modern military air vehicles, high lift systems are used to improve take-off and landing performance. For naval air vehicles, an improvement in the lift coefficient of a landing or approach configuration allows for arrested landings at reduced speeds or the ability to carry more weight back to the ship. For conventional take-off or landing (CTOL), improved lift to drag ratios allow for shorter take-off runs or greater payload capacity.

On a typical slotted high lift system, a hinged-shroud, in conjunction with a trailing edge flap is used to create a slot. The slot allows a jet, powered by the wing lower-surface high pressure, to energize the upper surface flow and cause an increase in lift as compared to a simple hinged flap system. The slot is set by varying gap and overhang, see Fig. 1. Gap is defined as the radius from the trailing edge of the shroud to a tangent point on the trailing edge flap. Overhang is defined as the horizontal distance from the trailing edge of the shroud to the leading edge of the trailing edge flap. The aerodynamic complexity of the high lift system makes design difficult. With that in mind, a cooperative international program was created to test two (2) representative military high lift configurations and utilize computational fluid dynamics (CFD) to understand the flow physics. In addition, it was hoped to be able to achieve the capability to use CFD as a future design tool. Therefore, the wind tunnel testing was conducted to understand the flow physics, optimize gap and overhang on selected configurations, and be used as a CFD validation data base.

A test of a high lift system on a representative military wing was conducted in the NASA Langley Research Center National Transonic Facility (NTF) wind tunnel. A sketch of the model is shown in Fig. 2. A photograph of the model installed in the tunnel is shown in Fig. 3. The testing was under the auspices of The Technical Co-operation Program (TTCP), a multi-national research collaboration program, and included NASA, DERA (UK), US Navy, and USAF. In addition to understanding the basic flow physics of military high-lift configurations, the test was also conducted for CFD validation.

The NTF wind tunnel is a cryogenic transonic facility at Langley Research Center and has an 8-foot by 8-foot test section. For this test, the normally slotted floor and ceiling were covered to form a solid wall tunnel. The tests were principally conducted at $M=0.2$ for Reynolds numbers of

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7.7, 3.8, and 1.4 million per foot (or 24.2, 11.9, and 4.4 million based on mean aerodynamic chord). The angle-of-attack range was -5 to 24 degrees. Mach and Reynolds number sweeps were also conducted to assess the effect on the aerodynamic properties. Tunnel force and moment data was corrected using a classical methodology (with out a separated wake correction) and using the WICS methodology.

The Diamond Wing, shown in Figs. 2 and 3, consisted of a semi-span, 40-degree leading and trailing edge-swept, thin wing. The semi-span was 2.6927 feet, see Fig. 2. Gap and overhang variation studies were conducted for shroud/trailing edge flap settings of 23/35, 17/35, and 0/20. The gap and overhang were optimized for the approach (23/35) and take-off (0/20) configurations. Leading edge flap angle was fixed at 22 degrees. Comparisons were also made with the wing with a 20 degree hinged flap and the wing in a clean configuration. Approximately 60 distinct gap/overhang conditions were tested on the three configurations. The gap was variable from 0.5 to 2.5% c and overhang was variable from -1.0 to 5.0% c in increments of 0.5% c . The fuselage was a generic design with a large flat region such that the flap/fuselage juncture could be sealed. A labyrinth seal and stand-off plate were used to reduce the effect of the wind tunnel boundary layer on the wing flow structure.

The high lift model was instrumented with approximately 450 pressure taps. The flap consisted of 132 pressure orifices. The fuselage incorporated approximately 80 pressure taps on the surface. Force and moment measurements were obtained with an external balance. In addition, the tunnel walls were heavily instrumented to record the surface pressure. Fluorescent mini-tuft data were acquired for the approach and takeoff configuration, as well as the maneuver (20 degree hinged flap) and cruise (clean) wings. Chemical sublimation studies were conducted on the approach configuration at 1atm for angles-of-attack of 8, 10, 12, and 14 degrees. Video deformation data was acquired on the approach configuration to determine the extent of the flap and shroud deflections, and thus the change in gap, under aerodynamic load.

The gap/overhang optimization was conducted to maximize the local lift coefficient at a representative range of angle-of-attack for the approach configuration and maximize the lift-over-drag ratio for the take-off configuration. The test evaluated the effect of trailing edge flap angle, shroud angle, high lift system effectiveness versus simple hinged flap, Reynolds and Mach number effects, and flap end seal effects in addition to the gap and overhang parametrics.

The paper will present an overview of the principal test results with selected data from other portions of the test. An uncertainty estimate will be provided along with an assessment of the test technique lessons learned.

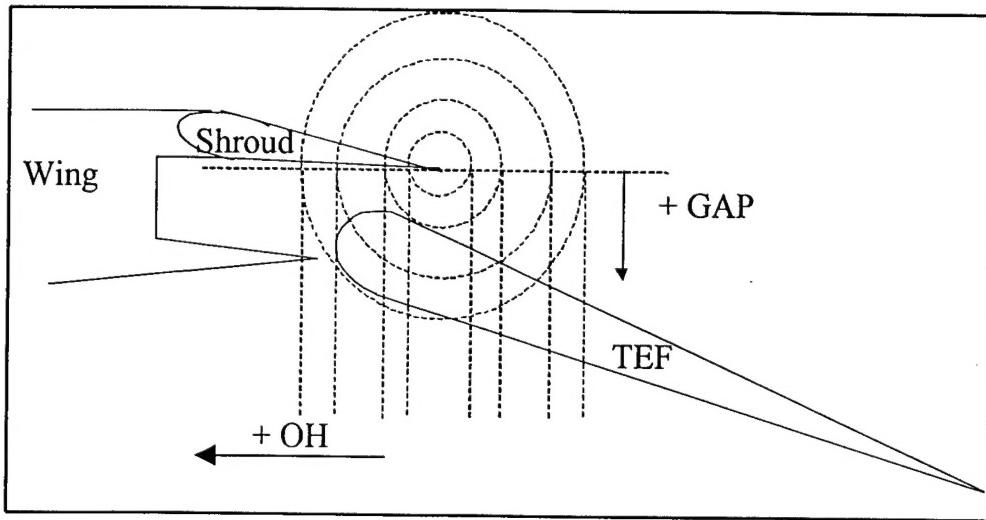
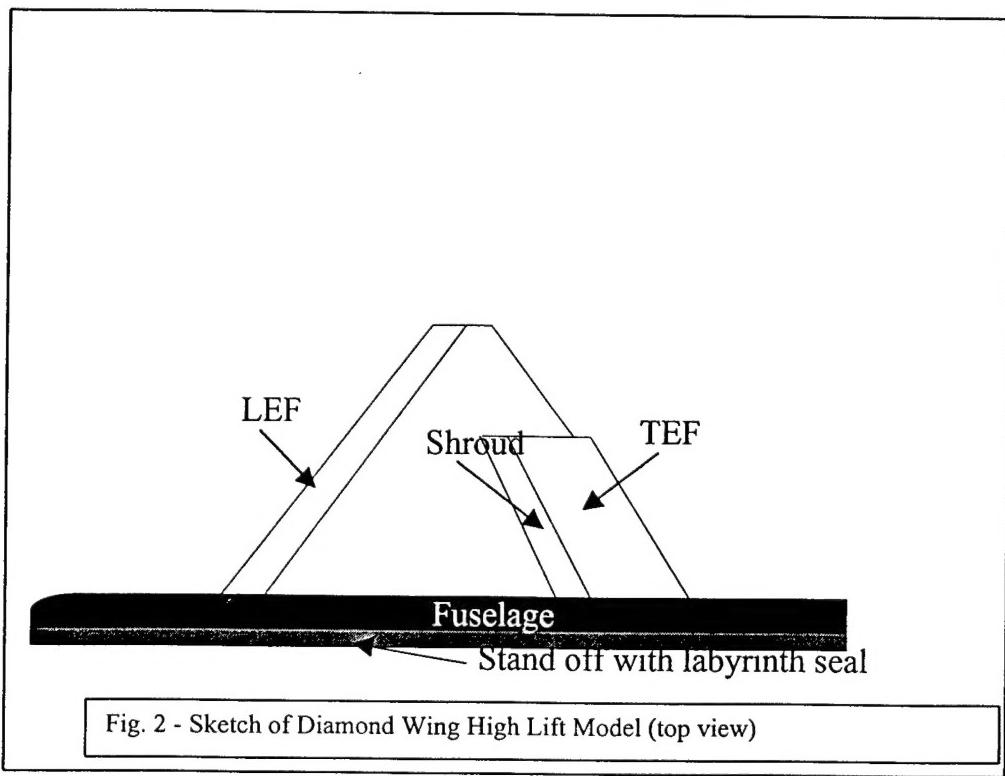


Figure 1. Sketch illustrating shroud, trailing-edge-flap (TEF), gap and overhang (OH).



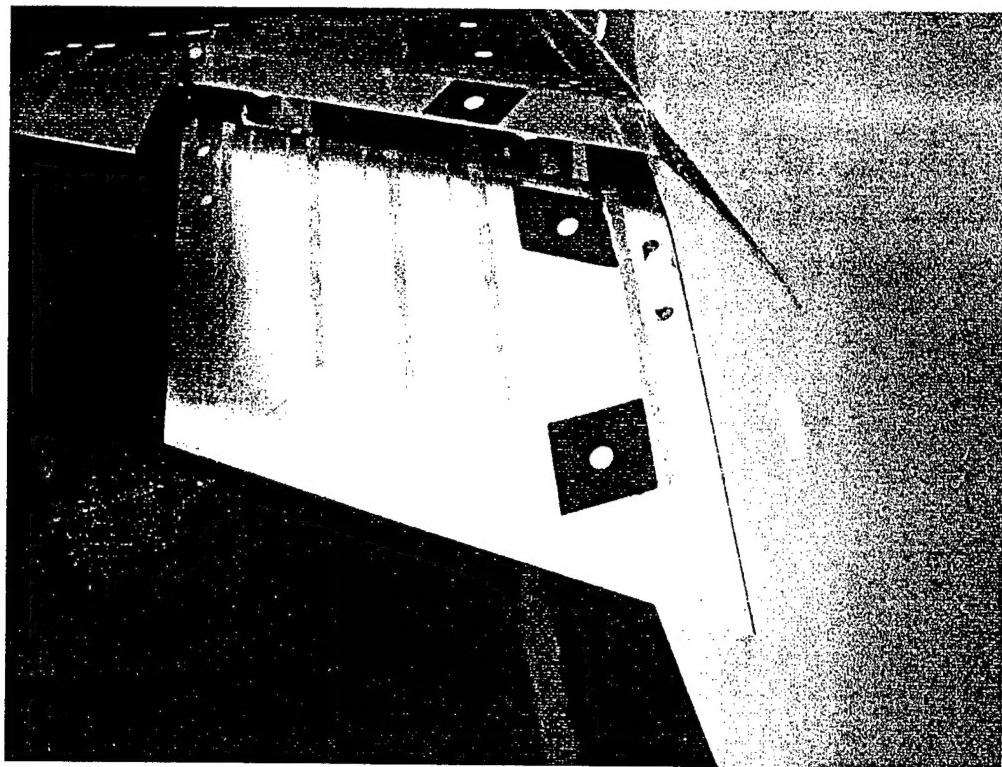


Fig. 3 – Diamond Wing High Lift system (looking upstream)

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